

## Research Article

# China's Spatial Economic Network and Its Influencing Factors

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With the deepening of reform and opening-up, China's economy has been further developed, but there is still a problem of uneven development. It is of great significance to completely construct China's economic spatial correlation network, to clarify the role and status of each province in the whole network, and to study the influencing factors of the national spatial economic network. In this paper, we employ the network analysis method to analyze China's economic development in the past 20 years. Based on the modified gravity model, we construct China's spatial economic network and explore the network structure from three aspects: the whole network structure feature, characteristics of individual provinces in the network, and block model analysis. The results show that (1) China's spatial economic network has strong internal cohesion, and the hierarchy of the network is becoming less and less obvious. However, the network density is low, and the overall network relationship still needs to be strengthened. (2) The different levels in economic development illustrate the obvious economic unbalance among provinces. (3) The block model analysis results demonstrated that coastal areas are more attractive to other provinces and are playing an important role in driving China's economy. Finally, we employ Quadratic Assignment Procedure (QAP) regression analysis to analyze the influential factors on spatial economic network. Numerical results show that the geographic proximity and the differences in six factors (industrial structure, level of economic development, degree of opening to the outside world, medical level, size of labor market, and infrastructure) have significant impact on the spatial economic network. Moreover, the influence of these factors on the economic relation among provinces has been gradually strengthened in recent years.

## 1. Introduction

With the process of reform and opening-up, China's economic development has made great achievements. However, the diversity of region economy is an important problem in economic development. At present, China's economic development has entered the new normal, which means that we are facing both opportunities and challenges. It is important to promote coordinated development among regions.

In recent years, the issue of regional coordinated development has received attention. In March 2019, Chinese Premier Li Keqiang at the second session of the 13th National people's Congress of the Communist Party of China proposed to promote coordinated regional development, to improve the quality of new urbanization, to focus on solving the problem of unbalanced development, to reform and

perfect relevant mechanisms and policies, and to promote the equalization of basic public services and the development of complementary regional advantages and urban-rural integration.

The national economic relationship directly affects the coordinated development of the regions. The flow of economic elements and differentiation of the industrial structure or other aspects are the basic forces to promote the establishment of economic links between provinces. Therefore, the purpose of this paper is to understand the structural characteristics of the spatial economic network and the influence of some factors on the spatial economic links, which is of great significance to improve the spatial economic network in order to realize the coordinated development of provinces.

Social network analysis is a useful method to study the relationship between social factors [1–3]. At first, it has been

used in the study of social network structure and social relationship at home and abroad. Later, it was found that it has strong adaptability to complex economic network [4–6]. Network construction is a key part of social network analysis. At present, there are many methods to build spatial network, among which the one based on the gravity model is one of the most common used methods. This method is widely used in the construction of trade network, tourism network, population migration network, and so on. In the classical gravity model, the economic gravity between two cities is proportional to the total economic volume and inversely proportional to the geographical distance. Compared with other methods of network construction, the gravity model method takes into account the factor of economic geographical distance. The advantage of the method is that it is also flexible, and researchers can modify the model according to research needs to make it more reasonable to reflect the gravity between nodes. In 2020, Ao built the urban comprehensive quality index through six basic indexes and incorporated it and the intercity distance into the gravity model. They analyzed the strength of spatial economic connection in the eight regions of Xiangxi Autonomous Prefecture [7]; Yang introduced the concepts of urban quality and economic distance into the gravity model and measured the economic gravity between 11 cities in Inner Mongolia [8]. These studies added new ideas to the construction of gravity models and better complement the theoretical content in this field. In this paper, the gravity model used is modified based on the above research. And the QAP regression method is considered to study the influencing factors of spatial economic network structure of China. The advantage of this method is that it can study the relationship between relational matrices. And it has been widely used in trade network to study the influencing factors of network structure [9–12]. In recent years, this method has been gradually used to study the economic network of individual provinces or some urban agglomerations in China, but there are few literatures used to study the entire structure of China's spatial economic network. In 2019, Shao carried out QAP regression analysis on the influencing factors of the economic network of the urban agglomeration in the middle reaches of the Yangtze River, and they found that the influence of geographical proximity on the network structure is very significant, and the influence of the differences in traffic accessibility, labor market scale, opening to the outside world, infrastructure, industrial structure, and investment on the network is increasing [13]. In 2020, Liu used the QAP regression to explore the influencing factors of urban financial relations in the Yangtze River Delta region. The results showed that the three factors of economic development level, population scale, and government intervention are significant positive [14]. Based on the QAP regression analysis method, this paper intends to employ some of the influencing factors used in the above literature as a reference and some new variables. To observe the effect of these factors on China's spatial economic network, this paper assumes that the differences of industrial structure, infrastructure, opening to the outside world,

economic development level, medical conditions, labor market scale, and geographical proximity between provinces have an impact on China's economic spatial network structure.

Based on the above literature, this paper will revise the gravity model and construct the network to observe the structural characteristics of China's spatial economic network. The influence factors of spatial economic network are analyzed by QAP regression, which is expected to provide decision basis for regional coordinated development in China.

## 2. Study Objects and Data Sources

In this paper, we select 31 provinces in China as the research object and observe the changes of China's spatial economic network in the past 20 years (2000–2019). The overall network structure characteristics and personal feature are explored. We only used the data of 2000–2018 to implement the QAP regression analysis because some data cannot be obtained. The bordered data in this study is obtained according to the map of China. Distance data are determined by distance between provincial capitals, while other raw data is obtained from the official website of China's State Bureau of Statistics. To eliminate inflation, we use the real GDP to reflect the gross domestic product of a province. Real GDP of provinces from 2000 to 2019 are shown in Figures 1 and 2. From the figures, China's economy is moving towards a positive trend, but there are still uneven developments between provinces.

## 3. Construction of Gravity Model

Spatial economic network can reveal the economic relations between provinces. The node of network represents one province, and the edge represents the economic gravity relationship established between two provinces. In this paper, the modified gravity model is employed which can make it more suitable for the research needs and can better measure the size of economic attraction between provinces. The modified gravity model is as follows:

$$T_{ij} = K_{ij} \frac{\sqrt{P_i G_i} \sqrt{P_j G_j}}{(D_{ij} / (g_i - g_j))^b}, \quad (1)$$

$$K_{ij} = \frac{G_i}{G_i + G_j},$$

where  $G_i$  in the formula is the annual Gross Domestic Product (GDP) of the province  $i$ ,  $g_j$  is the per capital GDP of the province  $i$ ,  $P_i$  is the year-end population of the corresponding province  $i$ ,  $D_{ij}$  is the distance between two provinces  $i$  and  $j$ , and  $b$  is the distance attenuation coefficient (here, we set  $b = 2$ ).

The process of constructing correlation matrix is as follows. Firstly, we need to calculate the gravitation matrix  $T$  of economic relation between provinces by the modified gravity model ( $n$  is the number of provinces):

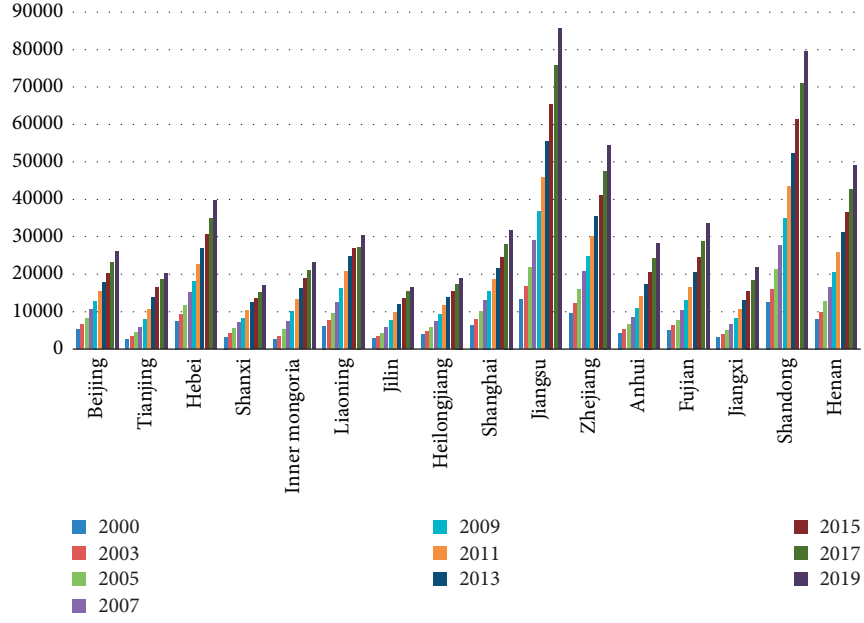


FIGURE 1: Real GDP of 16 provinces from 2000 to 2019.

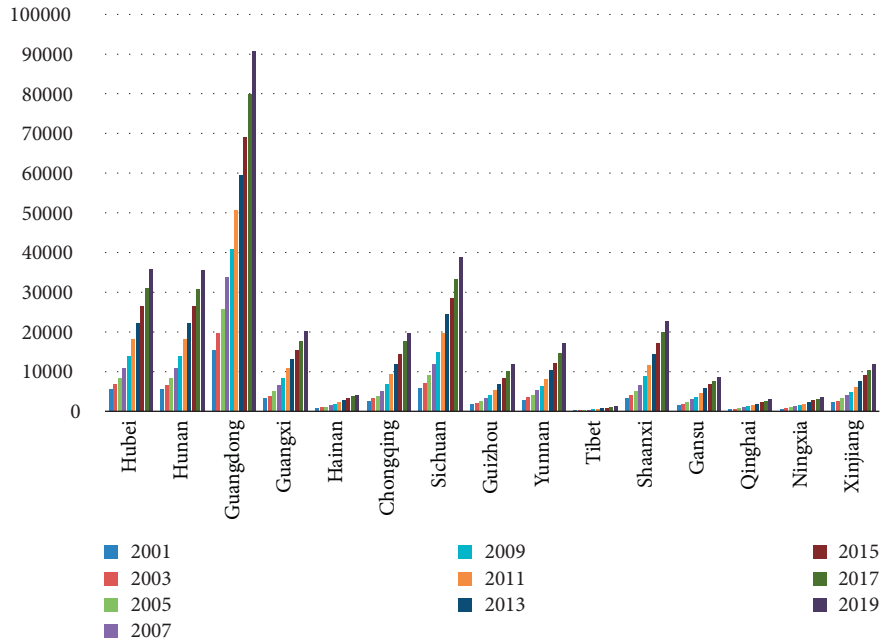


FIGURE 2: Real GDP of 15 provinces from 2000 to 2019.

$$\begin{bmatrix} T_{11} & T_{12} & \cdots & T_{1n} \\ T_{21} & T_{22} & \cdots & T_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ T_{n1} & T_{n2} & \cdots & T_{nn} \end{bmatrix} \quad (2)$$

Secondly, we construct the adjacency matrix according to the gravitation matrix  $T$ . If  $T_{ij} > \sum_{j=1}^n T_{ij}/31$ , then  $T_{ij} = 1$ , which indicates that there is an economic connection between two provinces. Otherwise,  $T_{ij} = 0$ , which indicates

that there is no economic connection between two provinces. Finally, we get an adjacency matrix with just the numbers 0 and 1; then, we construct the network according to the adjacency matrix.

#### 4. Structural Analysis of Spatial Economic Network

In this section, we use the Ucinet tool to characterize the spatial economic network. We construct China's spatial economic network for eight years in Figure 3.

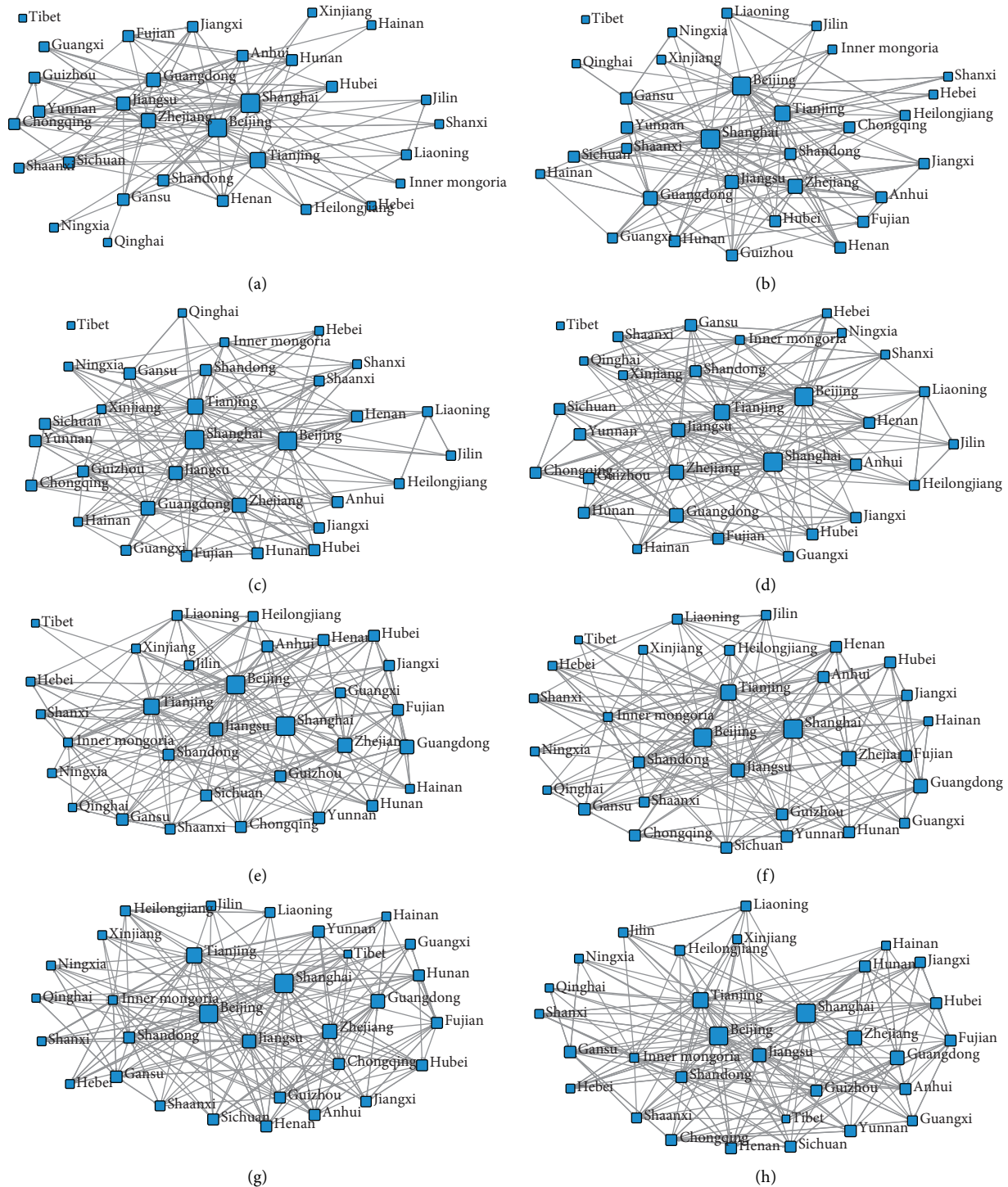


FIGURE 3: Visualization of China's spatial economic network. (a) Year 2000. (b) Year 2003. (c) Year 2006. (d) Year 2009. (e) Year 2012. (f) Year 2015. (g) Year 2018. (h) Year 2019.

From the structural changes of the network, we find the economic links between 31 provinces have increased in 20 years. Early, China's spatial economic network structure shows obvious marginalization of the central and western regions. However, the coastal areas play an essential role in the establishment of economic ties between provinces. This is closely related to the development strategy of the coastal

area and the “three major zones” implemented by the country before 2000. As the problem of regional economic development becomes more pronounced, there have been growing calls to regional even development. In order to reduce interregional economic disparities, the development strategy of Western Development, revitalization of old industrial bases in northeast, and development of the central

region in China were implemented in 2000, 2003, and 2006, respectively. From Figure 3, the economic links between provinces have increased since 2006.

**4.1. Features of the Overall Network Structure.** To explore the features of the overall network, we analyze three topological indices of spatial economic network including network density, cohesion, and hierarchy. Numerical results are shown in Figure 4.

The overall network density is the ratio of the actual numbers of associations in the network to the possible number, which reflects the degree of closeness of the relationship between the provinces. From Figure 4, China's spatial economic network density is increasing, but the increase is not large. The average of overall network density in the past 20 years is 0.22414. It indicates that the economic contact is weak between provinces, the cooperation between provinces need to be strengthened. The cohesion represents the degree of economic connection between three provinces. The average of overall network cohesion in the past 20 years is 0.45635, and it indicates that the cohesion of China's spatial economic network is stronger. The network hierarchy refers to the degree of unilateral connection between nodes. The higher the value of hierarchy is, the more obvious the hierarchical nature of the network structure is. It indicates the lack of bidirectional economic interaction between provinces. From Figure 4, we can find that the downward trend of the value of hierarchy is obvious. Between 2000 and 2006, the implementation of the three regional development strategies narrowed regional economic differences, the opening of China's high-speed rail in 2007 facilitated the flow of economic elements between provinces, and the approval of 18 free trade zones between 2014 and 2019 promoted the overall development of the eastern, central, and western regions.

The implementation of the economic development strategy and the improvement of transportation facilities in the past 20 years have led to a marked decrease in the level of China's economic network hierarchy. The concentration of economic development in the eastern region is gradually improving. At the same time, the economic links in regions have increased. Moreover, the cohesion and network density have also increased by a certain extent.

#### 4.2. Characteristics of Individual Network Structure.

Centrality is used to measure the function and status of network nodes in China's spatial economic network. In order to export the characteristics of each province in the spatial economic network, in this section, we study the importance of each province by means of UCINET in 2019, while the results in other years are shown in Tables 1–4. The study of the importance of network nodes from different angles corresponds to different methods. In this paper, the importance of nodes is judged by network structure information from the point of view of network topology. Based on the local properties of nodes, we select the index of degree centrality, which reflects the power and status of nodes in the network. The larger the value is, the more important the

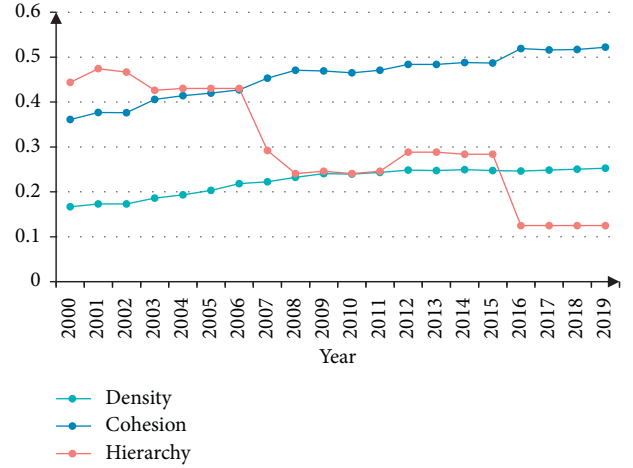


FIGURE 4: Topological indices analysis.

node is. Degree centrality can be divided into absolute degree centrality (the actual degree value of the point) and relative degree centrality (the ratio of absolute degree centrality to the maximum possible degree of the point in network). Equation (3) is the calculation method of relative degree centrality ( $n$  represents the absolute degree centrality and  $N$  represents the number of nodes in China's spatial economic network):

$$PC = \frac{n}{N-1}. \quad (3)$$

Based on the global properties, we select the betweenness centrality index to measure the ability of the node to be evaluated to control the links between other nodes in the whole network. The larger the value is, the more important the node is. Equations (4)–(6) are the calculation method of betweenness centrality:

$$b_{jk}(i) = \frac{g_{jk}(i)}{g_{jk}}, \quad (4)$$

$$C_{ABi} = \sum_j \sum_k b_{jk}(i), \quad (5)$$

$$BC = \frac{2C_{ABi}}{N^2 - 3N + 2}. \quad (6)$$

In Equation (4),  $g_{jk}$  is the number of shortest paths between nodes  $k$  and  $j$ ,  $g_{jk}(i)$  represents the number of shortest paths through node  $i$  between nodes  $k$  and  $j$ , and  $b_{jk}(i)$  represents the probability that node  $i$  in the shortcut between nodes  $k$  and  $j$ .  $N^2 - 3N + 2$  is the maximum number of shortest paths which through a node may exist.

In the directed network, the degree centrality of each node is divided into in-degree (the number of income associations of economy) and out-degree (the number of spillover associations of economy). The in-degree reflects the inflow of economic activities and the economic aggregation ability of provinces. The province is called the beneficiary of economic development if the in-degree is higher than the

TABLE 1: Degree centrality (in-degree).

Provinces	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018
Beijing	24	24	25	25	24	22	23	24	23	23
Tianjing	17	18	22	23	23	22	23	24	24	23
Hebei	2	3	3	4	4	5	5	6	5	5
Shanxi	2	2	2	3	3	4	5	5	4	4
Inner Mongolia	1	2	2	6	9	11	12	13	14	13
Liaoning	2	2	2	2	2	2	3	2	3	3
Jilin	1	1	1	1	2	2	2	2	1	1
Heilongjiang	1	1	1	1	2	2	2	2	2	2
Shanghai	25	25	27	27	27	26	24	25	25	26
Jiangsu	13	13	14	19	20	22	23	24	25	26
Zhejiang	15	15	18	18	18	17	18	15	16	16
Anhui	7	7	7	8	11	11	11	11	10	10
Fujian	3	4	3	5	6	6	6	6	6	7
Jiangxi	4	4	4	5	5	6	6	6	6	6
Shandong	7	7	7	11	11	12	12	13	13	15
Henan	6	6	7	8	9	9	10	10	9	9
Hubei	2	2	4	4	5	6	6	6	6	7
Hunan	2	2	3	3	5	5	5	5	4	4
Guangdong	10	11	11	12	12	10	8	7	8	8
Guangxi	1	1	2	2	1	1	2	2	2	2
Hainan	0	0	1	1	1	1	1	1	1	1
Chongqing	2	2	2	2	3	3	3	4	5	6
Sichuan	2	2	2	2	2	2	3	3	2	2
Guizhou	3	2	4	4	2	6	7	5	4	4
Yunnan	1	1	1	2	2	2	2	2	2	2
Tibet	0	0	0	0	0	0	0	0	0	0
Shaanxi	0	1	0	0	2	2	2	2	2	1
Gansu	0	1	3	3	3	4	5	5	5	5
Qinghai	1	1	1	1	1	1	1	1	1	1
Ningxia	1	1	1	1	1	1	1	1	1	1
Xinjiang	0	0	0	0	0	0	0	0	0	0

TABLE 2: Degree centrality (out-degree).

Provinces	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018
Beijing	6	6	6	7	7	5	5	6	6	5
Tianjing	5	5	6	6	6	5	5	6	7	6
Hebei	3	3	3	3	4	5	5	5	5	6
Shanxi	3	3	3	6	6	6	6	6	6	6
Inner Mongolia	3	3	3	6	9	8	8	8	7	7
Liaoning	5	5	5	5	7	8	9	9	5	5
Jilin	4	5	5	4	6	6	6	6	7	6
Heilongjiang	5	4	6	6	7	8	8	9	9	9
Shanghai	7	7	9	9	9	7	7	8	8	8
Jiangsu	3	3	4	5	5	5	4	4	4	4
Zhejiang	3	3	5	5	6	6	6	6	6	6
Anhui	4	4	4	4	3	3	3	3	3	3
Fujian	6	6	6	7	8	8	10	9	9	9
Jiangxi	6	6	7	7	7	8	8	8	8	8
Shandong	5	5	6	6	6	8	8	8	8	8
Henan	6	6	6	6	6	7	7	7	7	7
Hubei	7	7	6	6	7	8	7	7	7	7
Hunan	7	7	7	7	7	8	8	8	8	9
Guangdong	11	10	11	11	11	11	11	11	11	11
Guangxi	5	7	6	6	7	8	8	7	7	8
Hainan	2	2	6	9	6	8	8	7	7	7
Chongqing	8	8	8	8	9	9	10	8	8	8
Sichuan	8	8	8	8	9	10	10	10	9	9
Guizhou	7	8	7	9	10	10	12	12	10	11

TABLE 2: Continued.

Provinces	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018
Yunnanv	9	6	6	7	10	10	10	10	10	10
Tibet	0	0	0	0	0	0	2	5	8	10
Shaanxi	5	7	7	8	8	8	9	9	9	9
Gansu	9	12	10	10	11	10	10	11	11	11
Qinghai	0	1	4	4	7	6	7	6	6	6
Ningxia	1	2	4	7	5	6	6	6	6	7
Xinjiang	0	2	6	11	7	8	8	7	7	7

TABLE 3: Relative degree centrality.

Provinces	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018
Beijing	80	83.333	83.333	83.333	83.333	76.667	80	83.333	80	80
Tianjing	56.667	66.667	76.667	80	80	76.667	80	83.333	83.333	80
Hebei	10	10	13.333	16.667	16.667	20	20	23.333	20	20
Shanxi	10	10	10	20	20	20	23.333	23.333	20	20
Inner Mongoria	10	10	13.333	33.333	46.667	46.667	50	53.333	53.333	53.333
Liaoning	16.667	16.667	16.667	16.667	23.333	26.667	33.333	30	20	20
Jilin	13.333	13.333	16.667	13.333	20	20	20	20	23.333	20
Heilongjiang	16.667	20	20	20	23.333	26.667	26.667	30	30	30
Shanghai	83.333	86.667	90	90	90	86.667	83.333	90	90	90
Jiangsu	43.333	46.667	46.667	63.333	66.667	73.333	76.667	80	83.333	86.667
Zhejiang	50	50	60	60	60	56.667	60	50	53.333	53.333
Anhui	26.667	26.667	26.667	26.667	36.667	36.667	36.667	36.667	33.333	33.333
Fujian	23.333	26.667	20	30	36.667	36.667	40	36.667	36.667	40
Jiangxi	20	20	23.333	23.333	23.333	26.667	26.667	26.667	26.667	26.667
Shandong	26.667	20	30	43.333	40	50	50	53.333	53.333	60
Henan	23.333	23.333	23.333	26.667	30	30	33.333	33.333	30	30
Hubei	23.333	23.333	20	20	26.667	30	30	30	30	33.333
Hunan	23.333	23.333	23.333	23.333	26.667	30	30	30	26.667	30
Guangdong	46.667	40	46.667	50	50	43.333	40	36.667	40	40
Guangxi	16.667	23.333	23.333	23.333	23.333	26.667	26.667	23.333	23.333	26.667
Hainan	6.667	10	20	30	20	26.667	26.667	23.333	23.333	23.333
Chongqing	26.667	26.667	26.667	26.667	30	30	33.333	26.667	30	33.333
Sichuan	26.667	26.667	26.667	26.667	30	33.333	33.333	33.333	30	30
Guizhou	26.667	26.667	30	36.667	33.333	43.333	50	43.333	36.667	40
Yunnan	30	26.667	20	26.667	33.333	33.333	33.333	33.333	33.333	33.333
Tibet	0	0	0	0	0	0	6.667	16.667	26.667	33.333
Shaanxi	16.667	16.667	23.333	26.667	30	26.667	30	30	30	30
Gansu	30	23.333	36.667	36.667	36.667	33.333	36.667	36.667	36.667	36.667
Qinghai	3.333	6.667	13.333	13.333	23.333	20	23.333	20	20	20
Ningxia	6.667	13.333	13.333	23.333	16.667	20	20	20	20	23.333
Xinjiang	6.667	10	20	36.667	23.333	26.667	26.667	23.333	23.333	23.333

out-degree. The out-degree reflects the outflow of economic activities. The province is called the overflow side if the out-degree is higher than the in-degree.

The results in Table 5 show that the top provinces of the value of degree centrality are Shanghai, Jiangsu, Beijing, Tianjing, Inner Mongolia, Shandong, and Zhejiang, which are also economic beneficiaries in 31 provinces. This indicates that these provinces have the most economic relationships with other provinces. And they have strong economic agglomeration capacity compared with other provinces, more attractive to the inflow of funds, talents, and various economic resources. From the analysis of geographical distribution, it can be found that the vast majority of the beneficiary provinces are located in the coastal areas or the Yangtze River Delta region. These provinces are among

the first to develop in the course of China's economic development due to their unique geographical advantages, so they have a relatively solid economic foundation and are at the core of China's spatial economic network. Most of the provinces that belong to the spillover are located in the northeast and the central and western regions. These provinces have fewer economic links with other provinces and lack economic attraction in the whole economic network, so they will make more talents and resources flow to the developed regions.

The index of betweenness centrality reflects the same problem. The provinces with high degree centrality values are also with high betweenness centrality values, indicating that they are on multiple shortest paths between provinces, and they not only have strong economic attraction to other

TABLE 4: Betweenness centrality.

Provinces	2000	2002	2004	2006	2008	2010	2012	2014	2016	2018
Beijing	21.79	22.814	16.311	13.294	11.895	10.074	12.603	10.69	9.763	10.172
Tianjing	7.743	10.615	12.836	11.949	10.805	10.074	12.603	10.69	10.946	10.172
Hebei	0.034	0.022	0.02	0.045	0.04	0.148	0.165	0.186	0.104	0.098
Shanxi	0.034	0.022	0.02	0.127	0.114	0.115	0.217	0.186	0.104	0.098
Inner Mongoria	0.034	0.022	0.02	0.759	2.087	2.46	2.747	3.221	3.784	3.046
Liaoning	0.091	0.08	0.066	0.077	0.214	0.394	0.905	0.514	0.04	0.05
Jilin	0.034	0.022	0.126	0.02	0.09	0.1	0.104	0.074	0.162	0.05
Heilongjiang	0.188	0.344	0.292	0.316	0.303	0.5	0.501	0.575	0.592	0.66
Shanghai	23.536	22.795	20.212	16.517	14.463	13.662	10.952	15.027	14.535	13.003
Jiangsu	3.005	3.178	2.916	5.693	6.477	8.014	8.957	10.146	11.195	11.975
Zhejiang	4.538	3.753	6.1	4.831	4.657	3.87	4.271	2.927	3.497	3.335
Anhui	0.468	0.583	0.536	0.358	1.012	1.147	1.115	1.025	0.693	0.607
Fujian	0.246	0.393	0.122	0.34	0.653	0.726	0.956	1.018	1.05	1.239
Jiangxi	0.186	0.219	0.344	0.227	0.206	0.255	0.355	0.274	0.262	0.288
Shandong	0.592	0.208	0.636	1.596	1.249	2.028	1.945	2.077	2.193	3.011
Henan	0.318	0.397	0.287	0.367	0.602	0.616	0.935	0.845	0.532	0.478
Hubei	0.285	0.302	0.172	0.15	0.206	0.283	0.384	0.303	0.291	0.322
Hunan	0.37	0.359	0.344	0.227	0.206	0.345	0.451	0.36	0.349	0.394
Guangdong	4.275	2.358	2.928	2.975	2.939	1.863	1.446	1.283	1.688	1.324
Guangxi	0.102	0.359	0.325	0.15	0.206	0.255	0.355	0.274	0.262	0.353
Hainan	0	0.05	0.09	0.305	0.149	0.255	0.355	0.274	0.262	0.249
Chongqing	0.242	0.258	0.204	0.179	0.228	0.223	0.502	0.172	0.316	0.464
Sichuan	0.376	0.455	0.344	0.27	0.414	0.526	0.519	0.523	0.496	0.44
Guizhou	0.242	0.258	0.628	0.652	0.502	0.852	1.757	1.287	0.97	1.045
Yunnan	0.652	0.417	0.172	0.224	0.613	0.732	0.755	0.768	0.741	0.64
Tibet	0	0	0	0	0	0	0.01	0.074	0.394	0.64
Shaanxi	0.136	0.114	0.287	0.367	0.33	0.211	0.274	0.212	0.219	0.21
Gansu	7.943	1.283	2.049	1.147	1.029	0.648	0.749	0.866	0.865	0.792
Qinghai	0	0	0.02	0.02	0.134	0.094	0.203	0.074	0.085	0.082
Ningxia	0	0.022	0.02	0.158	0.02	0.094	0.112	0.074	0.085	0.098
Xinjiang	0.01	0.022	0.082	0.568	0.226	0.359	0.384	0.186	0.193	0.185

TABLE 5: Centrality of China's spatial economic network in 2019.

Provinces	Degree centrality			Betweenness centrality	
	Out-degree	In-degree	Benefit or not	Centrality	Centrality
Beijing	5	23	Benefit	80	10.061
Tianjing	6	23	Benefit	80	10.061
Hebei	6	5	Overflow	20	0.097
Shanxi	6	4	Overflow	20	0.097
Inner Mongoria	7	14	Benefit	56.667	3.704
Liaoning	6	3	Overflow	20	0.05
Jilin	7	2	Overflow	23.333	0.138
Heilongjiang	9	2	Overflow	30	0.563
Shanghai	8	26	Benefit	90	13.07
Jiangsu	4	26	Benefit	86.667	12.041
Zhejiang	6	16	Benefit	53.333	3.334
Anhui	3	10	Benefit	33.333	0.626
Fujian	9	7	Overflow	40	1.27
Jiangxi	8	6	Overflow	26.667	0.297
Shandong	8	14	Benefit	56.667	2.532
Henan	7	8	Benefit	26.667	0.325
Hubei	7	7	—	33.333	0.322
Hunan	9	4	Overflow	30	0.406
Guangdong	10	8	Overflow	36.667	1.064
Guangxi	8	3	Overflow	26.667	0.363
Hainan	7	1	Overflow	23.333	0.259
Chongqing	9	6	Overflow	33.333	0.459
Sichuan	9	2	Overflow	30	0.457



TABLE 5: Continued.

Provinces	Degree centrality			Betweenness centrality	
	Out-degree	In-degree	Benefit or not	Centrality	Centrality
Guizhou	11	4	Overflow	40	1.02
Yunnan	10	2	Overflow	33.333	0.66
Tibet	11	0	Overflow	36.667	0.807
Shaanxi	9	2	Overflow	33.333	0.256
Gansu	11	5	Overflow	36.667	0.837
Qinghai	6	1	Overflow	20	0.08
Ningxia	6	1	Overflow	20	0.08
Xinjiang	7	0	Overflow	23.333	0.184

provinces but also have strong control over economic resources. The central and western regions are still at the edge of the spatial economic network and lack dominant role in the process of economic development.

The above results indicate that although China's previous regional development strategy (South-to-North Water Diversion and project of natural gas transmission from West to East China) has enabled backward areas to be development, the greater beneficiaries are developed regions.

**4.3. Block Model Analysis.** Block model analysis is a method to divide a large number of nodes into several blocks and then examine the correlation between each block. We use the Built-in CONCOR (convergent correlation) programs in the UCINET software to build the block model. The operation path in UCINET software is *Network*  $\rightarrow$  *Roles/Positions*  $\rightarrow$  *Structural*  $\rightarrow$  *CONCOR* (set the maximum depth as 2 and the convergence criterion as 0.2).

After 2000, 15 years of economic ties between blocks are basically the same, and 2017 is one of them. So, this part takes 2017 to analyze the block model of China's spatial economic network. Finally, the network is divided into four blocks, and the results are shown in Table 6.

The density matrix of blocks is shown in Table 7. To get the image matrix, the overall network density is set to a threshold value as follows. If the block density is higher than the threshold, it is assigned to 1. Otherwise, it is assigned to 0. The image matrix in 2017 is shown in Table 7. In order to describe the relationship more intuitively, we draw a simplified graphic of image matrix, as shown in Figure 5.

The results show that the provinces in blocks I and II are roughly located in the coastal areas of the north and the south, respectively. And the provinces in blocks III and IV are roughly distributed in the north and south of the central and western part of China.

From the relationship between the four blocks, we find close economic connection between the provinces in block I, as well as between the provinces in block II. However, the economic relationship between these two blocks is less, which reflects the influence of the geographical location difference between the north and the south on the establishment of economic relationship between provinces. Blocks III and IV lack economic links, and the provinces within each block have few economic links. It means that the central and western

provinces economic connection is not closely enough, which is related to their weak economic foundation and economic development ability. From Figure 5, we find the economic links between block III and blocks I and II and between block IV and block I are all unidirectional, which once again proves that the coastal areas have a strong economic attraction to the central and western regions. This phenomenon is mainly related to the developed economy of coastal areas. China's coastal areas have the geographical advantage of adjacent sea areas. The convenient shipping conditions make them essential areas for China to import and export to other countries, so its own economic development is good, and it can attract the inflow of talents in the undeveloped areas of the central and western regions.

There is a two-way link between blocks II and IV. This result reflects the central and western provinces of the south have some economic attraction to the southern coastal areas in recent years. They show that the economy of the central and western provinces in the south is developing rapidly, especially in the upper-middle reaches of Yangtze River in recent years. This is because the adjustment of industrial structure and the improvement of transportation conditions in the upper-middle reach Yangtze River, which has attracted a larger number of enterprises in the Pearl River and Yangtze River deltas. Therefore, the central and western provinces of the south have a good development momentum and have established two-way economic ties with the coastal areas.

## 5. Analysis of the Influencing Factors of Spatial Economic Network

The problem of collinearity may occur when analyzing the influencing factors of China's spatial economic network because of the adjacent relationship between provinces. QAP can avoid this problem as a specific method to study the relationship between relational data. QAP is a method of comparing the similarity of two square matrices and giving the correlation coefficient between the two matrices. The purpose of QAP regression analysis is to study the relationship between the influence matrix and spatial economic network.

**5.1. Variable Selection and Model Construction.** In the analysis of the block model of the spatial economic network, we found the geographical distance between provinces has a certain influence on the establishment of economic

TABLE 6: Result of regional partition in 2017.

Blocks	Provinces
I	Beijing, Tianjin, Jiangsu, Inner Mongoria, Shandong
II	Guangdong, Fujian, Shanghai, Zhejiang
III	Hebei, Shaanxi, Ningxia, Liaoning, Qinghai, Jilin, Heilongjiang XinJiang, Gansu, Shanxi, Chongqing
IV	Hunan, Yunnan, Tibet, Henan, Zhejiang, Anhui, Hubei, Jiangxi Guangxi, Hainan, Sichuan, Guizhou

TABLE 7: Density matrix and image matrix in 2017.

Blocks	Density matrix				Image matrix			
	1	2	3	4	1	2	3	4
I	0.450	0.050	0.182	0.218	1	0	0	0
II	0.100	0.333	0.023	0.591	0	1	0	1
III	0.873	0.318	0.118	0.033	1	1	0	0
IV	0.764	0.841	0.041	0.027	1	1	0	0

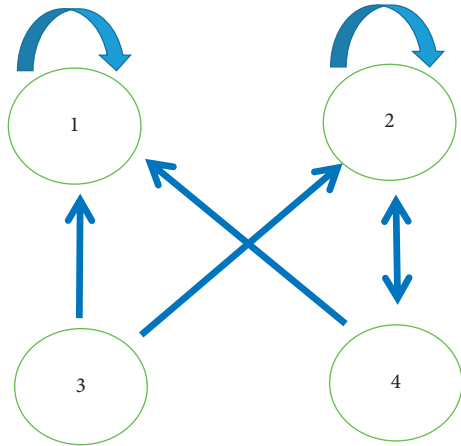


FIGURE 5: Simplified graphic of the image matrix.

relations. Therefore, we consider adding indicators of border or not (BOU) and urban geographical distance (UGD) into the model to reflect the impact of geographical distance on economic correlation. From the economic ties between coastal provinces, it seems easier to establish economic ties between provinces with similar levels of economic development. However, this is only a guess for the situation in developed regions. Is this a reasonable guess for the whole network? So, the index of per capita GDP (PAG) and foreign investment (FI) will be included in the QAP regression model as a reflection of the level of economic development. According to the previous literatures, it is found that population mobility, infrastructure differences, and urban industrial structure differences also affect the formation of spatial economic network. The larger the scale of the labor market, the more the employment opportunities. The region with more employment opportunities will attract more talent inflow and then promote the establishment of economic links between provinces. So, we establish the labor market scale (LMS) difference matrix to reflect the population flow between provinces. A similar industrial

structure means that the two cities have similar stage and direction of development, and the two provinces are more likely to be linked. Therefore, the index of the added value of the secondary (PSI) and tertiary (PTI) industries are used to reflect the economic development model of the city. In addition, the difference in the proportion of road area (PRA) is used to reflect the difference in infrastructure between provinces. Moreover, the number of health personnel (NHW) reflects the medical conditions in a province. The number of foreign-invested enterprises (FIE) is used to present the extent of the province's opening to the outside world.

Before QAP regression analysis, we calculated the difference matrix of the corresponding indicators of each province in the spatial economic network. The above variables are appropriately treated with reference to the treatment methods in previous literatures, as shown in Table 8. The regression variables are shown by the relationship matrix of two provinces.

The spatial economic correlation matrix of provinces is used as the explained variable, and the index in Table 8 is used as the explanatory variable to construct the QAP regression model. The model is given as follows:

$$Y = f(\text{BOU}, \text{IDM}, \text{PAG}, \text{FI}, \text{FIE}, \text{PSI}, \text{PTI}, \text{PRA}, \text{LMS}, \text{NHW}). \quad (7)$$

The  $Y$  represents the spatial economic correlation matrix, BOU, IDM, PAG, FI, FIE, PSI, PTI, PRA, LMS, and NHW, are all relational matrices. The purpose of QAP regression is to study the effect of the above selected variables on China's spatial economic network.

**5.2. QAP Regression Analysis.** After determining the explanatory variables, we use UCINET software to QAP regression analysis. The operation path is *Tools* --> *TestingHypotheses* --> *QAP* --> *QAPcorrelation*. It is evident that the recent data can better reflect the current real economic development. So, we choose the data from

TABLE 8: Variable selection for QAP analysis.

Variables	Signification	Data processing
BOU	Whether provinces are adjacent	Build a binary matrix
IDM	Distance matrix between provinces	Take the distance between the provincial capitals as the standard
PAG	Per capita GDP	
FI	Foreign investment	
FIE	The number of foreign-invested enterprises	
PSI	The proportion of the added value of the secondary industry	Calculate the difference between the provinces after standardized processing
PTI	The proportion of added value of tertiary industry	
PRA	Proportion of road area	
LMS	Labor market size	After normalization and difference, the matrix is converted into a 0-1 matrix with the row mean value as the threshold
NHW	The number of health personnel	

2011 to 2018. The results of QAP regression analysis are shown in Table 9.

The purpose of QAP regression is to study the regression relationship between multiple matrices and one matrix, which requires that all variables must be square matrices. In the results of QAP regression analysis, the standardized regression coefficient of each explanatory variable and test of significance will be obtained. If the  $P$  value corresponding to the regression coefficient is less than the significant level (10%, 5%, and 1%), it is considered that the corresponding variable is significant in statistical sense, and the contribution of the corresponding variable to the explained variable is considered to be significant [15, 16].

From Table 9, the value of  $R^2$  is between 0.35 and 0.43 in 2011–2018, which indicates that the influencing factors selected in this paper can explain 35% ~ 43% of the changes of China's spatial economic network. Compared with the existing literatures, the value of  $R^2$  is already high [13, 14]. As shown in Table 9, the value of  $R^2$  in 2018 among these eight years is the largest. This means that these 10 factors can better explain the formation of China's spatial economic network structure in 2018, which is related to the China's current economic development model.

The results showed that the regression coefficient of IDM is significant at 1% and BOU is significant at 5% between 2000 and 2018. The regression coefficient value of IDM is negative and the BOU is positive, indicating that the geographical proximity has a significant impact on the spatial economic association. The closer the two provinces are geographically, the easier it is to establish economic ties.

Per capital GDP is an important macroindex to measure the economic development of a region. Foreign investment refers to the total amount of funds invested by foreign investors and Chinese investors in cooperation in China. Both indicators can reflect the basic economic situation of a region. It can be found that the regression coefficients of the two indicators are negative and have passed the significance level test in 2011–2018. The results verify the hypothesis that it is easier to establish economic links among provinces with a similar level of economic development. According to official data, the provinces with high per capital GDP in 2018 are Beijing, Shanghai, Tianjing, and Jiangsu, while the ones with high foreign investment are Guangdong, Jiangsu,

Shanghai, and Zhejiang. And the actual situation in China proves that there are indeed more economic links between these provinces.

The secondary and tertiary industries reflect the industrial structure of a province. From Table 9, the regression coefficients of the two indicators are negative and have passed significant test, which shows that the closer the industrial structure is, the easier it is to produce economic relationship between provinces. The absolute value of the coefficient corresponding to the PSI is larger than that of the PTI. According to the Chinese background, China's secondary industry mainly consists of various industrial categories and the tertiary industry mainly includes service and logistics industry. With the improvement of living standard, people pay more attention to the quality of public service. At the same time, the rapid development of transportation industry and the arrival of data era make people's consumption behavior change. A larger number of online consumption has made the logistics industry develop rapidly. This is the reason why the tertiary industry has a greater impact on China's spatial economic relations than the secondary industry in recent years.

The proportion of road area reflects the infrastructure situation of a province. The results show that the PRA has a significant impact on the establishment of economic relationships between provinces, indicating that the smaller the difference of infrastructure between provinces, the more economic correlation. Infrastructure is a public service system used to ensure the social and economic activities of a region. Only when a region has a sound public service system, it will be more focused on economic development. This shows that provinces with similar infrastructure backgrounds are more likely to have economic contacts.

Foreign-invested enterprises refer to those enterprises established within the territory of China and invested by foreign investors. The number of foreign-invested enterprises reflects the degree of opening to the outside world of a region and contributions to the expansion of its labor market. From Table 9, the regression coefficient of FIE is significant at 1%, indicating that the difference in the number of foreign-invested enterprises between provinces had led to the establishment of economic ties, which is related to the flow of labor force between provinces. Data

TABLE 9: The result of QAP regression analysis.

Variables	2011	2012	2013	2014	2015	2016	2017	2018
BOU	0.094***	0.071**	0.124***	0.114***	0.11***	0.092***	0.077**	0.08**
IDM	-0.304***	-0.315***	-0.267***	-0.27***	-0.241***	-0.231***	-0.231***	-0.218***
PAG	-0.272***	-0.261***	-0.287***	-0.288***	-0.356***	-0.308***	-0.278***	-0.25***
FI	-0.38***	-0.416**	-0.22*	-0.282**	-0.152**	-0.277**	-0.262**	-0.261***
FIE	0.50***	0.556***	0.417**	0.475***	0.346***	0.452***	0.408***	0.396***
PSI	-0.145**	-0.143**	-0.142**	-0.135**	-0.098	-0.093*	-0.105**	-0.1**
PTI	-0.24**	-0.275**	-0.25**	-0.098**	-0.196**	-0.19**	-0.214**	-0.222***
PRA	-0.151***	-0.166***	-0.155***	-0.161***	-0.164***	-0.165***	-0.174***	-0.163***
LMS	0.217***	0.292***	0.338***	0.386***	0.387***	0.367***	0.364***	0.394***
NHW	0.142***	0.071**	0.138***	0.083**	0.096***	0.067**	0.061**	0.07**
$R^2$	0.349	0.346	0.413	0.403	0.401	0.389	0.391	0.426

Note. \*, \*\*, and \*\*\*, respectively, represent the significance level of 0.1, 0.05, and 0.01.

released by China's Ministry of Commerce show that the eastern part of China has been the main concentration of foreign investment, and the number of investment enterprises in the eastern part of China is more than that in the central and western regions, which is also the reason for the flow of labor force to the eastern regions. Therefore, in order to reduce the difference, our country should actively encourage the transfer of foreign capital to the central and western regions, so as to fundamentally improve the economic base of central and western regions and promote economic relationships between provinces.

In addition, the LMS and NHW indicators have a significant positive impact on the formation of spatial economic network. It shows that the population mobility caused by the difference of employment opportunities and medical conditions among provinces promotes the economic correlation between provinces. From the change of regression coefficients in 2011–2018, we know that the LMS is exerting more and more influence on China's spatial economic network, which indicate the labor market scale between provinces still has great difference. The effect of NHW is becoming smaller and smaller, indicating the medical condition is gradually balanced in various regions of China.

## 6. Conclusion

China's spatial economic network based on the modified gravity model is constructed in this paper. We investigate the characteristics of overall network structure and its internal structure by the network analysis method. We employ the QAP regression analysis method to study the influencing factors of the spatial economic network. According to the numerical results, we derive the conclusion as follows. (1) In 2000–2019, the cohesion of every three provinces in China's spatial economic network has been strengthened year by

year, the network density has increased year by year, and the network hierarchy has been weakened year by year. It shows that the implementation of the development strategies, such as the great development of the west, the revitalization of the old industrial base in the northeast, and the rise of the central region, has gradually improved China's spatial economic network structure. However, the network density is still low, indicating that the economic relationship between provinces needs to be strengthened. (2) The economic spillover and benefit of provinces present the unbalanced characteristics of economic development between provinces. The data in 2019 show that there are only seven beneficiary provinces, most of which are located in coastal areas, including Shanghai, Jiangsu, Beijing, Tianjing, Inner Mongolia, Shandong, and Zhejiang. The economic spillover provinces are mainly located in the central and western regions, including Qinghai, Ningxia, Guizhou, Yunnan, and Guangxi, which belong to the regions with relatively backward economy. According to the degree centrality and betweenness centrality of each provinces, Shanghai, Jiangsu, Beijing, and Tianjing are key nodes in China's spatial economic network, and they have strong ability to master economic resources. Hebei, Shanxi, Qinghai, and Ningxia are marginalized in the spatial economic network, and they play a small economic role and need to improve their own economic development ability. (3) The result of the block model analysis shows that the developed coastal areas have obvious economic attraction to the central and western regions. The reason is that the level of economic development in the central and western regions of China is relatively weak, so many central and western regions of the population to seek development to the coastal area flow. In addition, the economic strength of the central and western regions of the south has been increasing in recent years. (4) The QAP regression analysis results show that border or not, the

geographical distance, per capita GDP differences, foreign investment differences, labor market scale differences, differences in the added value of the secondary and the tertiary, proportion of road area, number of health personnel, and number of foreign-invested enterprises significantly impact on China's spatial economic association. Among the indicators used in this paper, the regression coefficient corresponding to the number difference index of foreign-invested enterprises is the largest, which means that China's opening to the outside world policy has a strong influence on China's spatial economic network structure.

Based on the conclusion above, this study proposes the following policy recommendations. First, economic cooperation and interaction should be strengthened among neighboring provinces. The combination of countless such small cooperation circles can promote the increase of the density of the whole China's spatial economic network. In addition, the national policies need to consider how to improve the traffic conditions in different regions of the country and narrow the economic distance between provinces by reducing the time consumption of economic factor transportation. Second, the central government should not only stimulate the coastal provinces with strong ability to control economic resources, such as Shanghai, Jiangsu, Beijing, Tianjing, Shandong, and Zhejiang, to play an economic driving role, but also focus on strengthening the transmission function of the provinces that play the role of "intermediary" in China's spatial economic network. At the same time, some targeted regional development policies should be formulated. We should also carry out accurate control in view of the different positions and roles of provinces and blocks in the spatial network, so as to enhance the synergy of China's spatial economic network. Finally, with the arrival of big data era and the vigorous development of the high-speed rail industry, the provinces of central and western regions such as Hebei, Shanxi, Qinghai, and Ningxia, should seize the opportunity, actively adjust the local industrial structure, vigorously develop the local service and logistics industry, and respond positively to the policy of opening to the outside world. At the same time, it is necessary for provinces to control the large loss of labor force by improving health care and infrastructure and expanding the labor market. All provinces should fundamentally improve their economic development, so as to promote the formation of two-way cooperative links between underdeveloped and developed provinces, rather than forming one-way links through population flows caused by difference in resources and employment opportunities between provinces. Otherwise, it will deepen the degree of imbalance of China's regional economic development.

### Data Availability

The data used to support the findings of this study may be released upon application to the China National Bureau of Statistics and can be checked at <http://www.stats.gov.cn/tjsj/nds/>.

### Conflicts of Interest

The authors declare that they have no conflicts of interest.

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